Fermilab

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Trip Report

LHC IRQ Collaboration
US-IT-HXTU Installation

February 28 – April 26, 2000
CERN, Geneva Switzerland

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May 9, 2000

Summary

The goal of this trip was to define technical guidelines for the installation of the "United States-Inner Triplet-Heat eXchanger Test Unit". The so-called US-IT-HXTU will have the job of verifying the design of the critical element of the LHC's superfluid helium cooling system at full scale, in collaboration with the Cryogenics for Accelerators group (ACR) at CERN. The pieces of hardware were designed by Fermilab Engineering and Fabrication Department and fabricated by American industries (Meyer's Tool and PHPK). All parts arrived at CERN by February 14th.
This trip aimed at integrating the work previously done at FNAL and assesses the follow-up to the assembly. The purpose of my tasks was largely driven by the design of interface components, overseen on the assembly process and technical needs. As part of the visit, the help with the mechanical assembly, the survey as well as the cryogenics, DAQ and electrical interface definitions were also considered with care. The stages of this charge included the organization of the installation, inspection of our hardware in order to meet the CERN safety installation requirements. Pragmatic studies dedicated to the choice of assembly process were carried out. Discussions and ideas were shared in order to organize the test program and decide on the test program baselines. Another purpose was to issue documents in order to target testing procedures. Furthermore, the fit of new parameters with the theoretical model was under focus.
An interesting aspect of the trip was the fieldwork, i.e. to concretely help with the set-up of the experiment, to constitute a basic team and a strategy for the US-IT-HXTU installation and commissioning.

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OVERVIEW ON THE INSTALLATION OF THE US-IT-HXTU

The first day was mainly dedicated to touring, with Rob van Weelderen, the cryogenic hall SM18, where the test will be performed. Rob van Weelderen is currently leading the US-IT-HXTU project at CERN. This overview of the SM18 cryogenics facilities was judged to serve the purpose of foreseeing the installation of the US-IT-HXTU. Interfaces were defined for the connection of our feed-box to the SM18 cryogenic valve box.
The cryogenic valve box is located in between the one for the quadrupole magnetic test bench and the one for the Cryolab Long Test facility (CLTF).

The second day, a meeting for a crash introduction of the test-bed was conducted, with ACR staff members, at the SM18. An overview on each of the four modules, turnaround, feed-box permitted to familiarize them with the hardware.
The same scope served the first meeting (03/8/00) that we organized in collaboration with Rob van Weelderen. I introduced the project and a draft schedule, which served as a working support. A list of tasks permitted to discuss the strategy to apply. Technical guidelines were defined. Minutes can be consulted.
The 17^{th} of March, the installation schedule was issued, taking into account the time requested for the design and fabrication of the supporting system (see 1.1). The given schedule is useful to have an overview on the various tasks to be performed.
The third days we removed the feed-box from its crate. Therefore we could check the display of the feed-box top plate pipes in order to match them with the cryogenic valve box supply pipes.
I detailed, to the assembly team, the content of the boxes of accessories shipped with the crate (bellows, squirm protectors, sensors, MLI, valves…). Each accessory was named and listed at Fermilab. A copy of the list was given to Rob van Weelderen as well as the engineering note folders.

All steps and problems met during the installation of the experiment were strictly reported to FNAL, using the project web page as a communication tool, http://tspc01.fnal.gov/darve/heat_exchanger/instrumentation.html. Prior to the trip, this home page, globally, introduced the project and permitted to transmit various parameters (cryogenics, instrumentation, electrical, DAQ and control) by means of drawing, schematics and photos.
The assembly team had continually to be cognizant of the difficulty to install an American-made hardware in a European coded environment. A rational approach regarding the preparation was requested in order to accelerate the assembly process that turn out to be, sometimes, slowed down because of the non- standardization of the processes and instrumentation.

1 ASSEMBLY

1.1 THE SUPPORTING SYSTEM

An important delay was noticed for the design and fabrication of the supporting system for the US-IT-HXTU. Although all information was available through the web, the lack of time prevented CERN team to start with the design. Therefore, the first priority was given to the design of the supporting system with the help of Roger Looserand. The system is dedicated to raise parts within a 1.4% slope, simulating the largest slope of the LHC machine, hence the most conservative case. For safety reasons, Alain Bezaguet, ACR/SR section leader, requested that supports were made out of steel. Tobias Dobers, surveyor, validated the design and estimated that the tuning system needed for the alignment process was satisfying regarding the lack of time to build up a more elaborate system. The first pieces of support designed were dedicated to support the feed-box. Then nine additional supports were designed and manufactured. A part of this work also consisted on the follow-up of pieces machined at the main CERN workshop. The supports were designed (Feb. 29 to Mar. 22), machined (Mar. 8 to Apr. 18) and all of them were anchored to the floor the 19th of April.

1.2 INTERCONNECTION DESCRIPTION

With the collaboration of the assembly technicians, we broached the description of the interconnection. Three main assemblies of the module components were under focus. For each of the five interconnections:

- the corrugated heat exchanger tube will be directly welded to its mate extremity (see 1.4).
- internal pipes will be welded to their respective bellows.
- vacuum vessel is connected to its bellow by means of bellows and 28 clamps.

A statement on the mounting scenario and the leak check while welding the corrugated HX tube as well as interconnection bellows, was discussed with Claude Masure. This professional welder was appointed by ACR/SR for six months in order to work on the US-IT-HXTU assembly.

Regarding the connection to the SM18 cryogenic supply lines, I studied the interface position and dimensions. The SM18 cryogenic valve box is composed of 3 pipes: LHe supply, GHe return and the return line for the JT heat exchanger. A stainless steel outer shell will enable to locate them in the same vacuum insulation volume as the one of our feed-box. Fermilab provided connection hoses, which will be installed in between the feed-box and the cryogenic valve box.

1.3 DESIGNS UPDATE TO MEET THE CERN REQUIREMENTS

The 16th of March, another meeting were conducted at the SM18 in order to check if the FNAL assembly processes would meet the CERN safety requirements. A memorandum was issued in so far as some of the initial solutions did not meet the CERN safety installation requirements.

For instance the assembly of the simulator magnet bellow inner diameter was too loose. The solution of filling the gap, using stainless steel strips machined at FNAL, was rejected. Instead, extra parts matching each bellow diameters were designed and machined.

The assembly of the corrugated HX tube was not accepted either (see 1.4).

The SM18 supply and return helium pipes will be welded to FNAL hoses then welded to pipes on the top of the feed-box. Prior we planned to butt weld each of these joints. An alternative technique was preferred in order to facilitate the welding process. Hence, adaptation parts for connecting the feed-box to the cryogenic valve box were also designed.

Regarding the purge circuits, Bruno Vullierme and Lionel Herblin proposed that we connect those two circuits to their helium return system flange. Some adaptation parts were designed and machined.

Claude Masure did some more weld work in order to adapt our hand valves to the CERN flanges.

1.4 DEFINITION OF THE CORRUGATED HX TUBE ASSEMBLY.

Saturated He II will flow in the corrugated HX tube and will remove the heat from the pressurized He II. Discussions were underway regarding the welding of the corrugated HX tube. Concretely, for each module, the copper corrugated is brazed to a stainless steel fitting on both ends. Then, each fitting and its mate on the next module should be welded to shape the string. There were some concerns regarding the brazed zone location, which was unlikely to be leak tight after the weld. The CERN assembly team, lead by Alain Bezaguet was reluctant to accept this technology. It was decided to cut each female fitting in order to create more room. This additional distance between the weld and the brazed zone will ensure the ability to control the temperature at this interface, while welding.
The choice of the welding process to handle requested a preliminary test. For this purpose, a sample of the corrugated HX tube was shipped from FNAL to CERN. A coupon simulating the dimensions of the copper corrugated HX tube and fitting was fabricated. Digital and infrared thermometers, located at this interface with the brazed zone, measured 400C while welding with the proposed scenario. The temperature used by US-companies for brazing the copper to the stainless steel bracket was 732C. Therefore, this study was successfully carried out and we authorized this new procedure. Documentation attempts to summarize the test. A welding procedure specification is written and will permit the reproducibility of this assembly.

2 SURVEY

2.1 SURVEY FOR THE INSTALLATION

We first defined the reference points with Tobias Dobers in order to install the feed-box underneath the cryogenic cryogenic valve box. Starting from two reference points, we indicate the position for each support. This was made easier thanks to the jig designed by Roger Looserand. Rodrigue Feas used chemical bolts to anchor supports to the floor.

2.2 CORRUGATED HX TUBE DEFLECTION MEASUREMENTS

There was a compelling reason to study the deflection of the corrugated HX tube. For each module, this component is made out of 0.7-mm thick copper tube. Regarding the arranged assembly, we could see that, once assembled, both extremities of the corrugated HX tube would accept a large deflection. If we could not ensure the deflection over its total length, the quantity of stored helium II (liquid phase) would be unknown. The reaction of the cryogenics process would not be mastered therefore measurements would not be consistent. Hence, it was very controversial to use the corrugated HX tube without adding any extra supports in order to avoid the large deflection. Two bracket supports were added on each module extremities in order to straighten the corrugated tube and to accommodate the deflection. They were designed on the basis of the existing one, out of a 2-cm thick composite plate (Vetresite®). The fabrication of these brackets went on quickly and we were able to mount them before we check the final deflection. Then, a survey for the final deflection was organized.

In collaboration with Roger Looserand we developed a tracker, kind of sub-marine that could be inserted in the corrugated HX tube. A LED, carried by the sub-marine, permits to measure the deflection by the mean of a theodolite. Springs and PVC® skates were used to guide the sub-marine. Roger Looserand machined a tube assembly in order to check the strength of the sub-marine to be inserted into the corrugated HX tube, through its fittings, which diameter is smaller.
The final experiment was conducted on the overall structure sitting on horizontal blocks. DAQ permitted to record data. The results of the study showed 6-mm sags with an average of 4-mm sags axially distributed in between the seven composite supports for each module. The accuracy of the measurement is equal to ~1 mm. Two more measurements should be performed once modules sit on their final supports. Those results will be implemented in the theoretical model. A memorandum detailing this study is also accessible through the web page.

2.3 INSTALLATION OF MODULES

The 20th of April, we finally installed the first three modules on their supports. Is was a chance that Tom Nicol could also be there and witness the "come true" of several years of work.
Later on, the next step was to check that the piping system is positioned correctly and is connectable to their respective bellows. Following the installation, we met a problem of distance larger than expected at interconnections. The use of the rail was proved to be effective to slide the supports and locate them properly.

The assembly is under way and the welding of interconnection bellows should start soon. Each bellow was leak checked at FNAL and was assigned to a given interconnection. A sketch of the interconnection as well as a traveler book was send to CERN with the engineering note. The description of the use of the shield bridge and the installation of the wrapped MLI, is enclosed in the so-called folder.

3 CRYOGENIC, INSTRUMENTATION AND DAQ

3.1 CRYOGENIC PARAMETERS

I met Bruno Vullierme and Lionel Herblin the 22nd of March. We defined the cryogenic needs for our test bench. It was decided that the helium guards were not necessary. Nevertheless, a dedicated leak check should be performed on the sub-atmospheric circuits.

It is intended to provide the US-IT-HXTU with sufficient helium flow (18g/s) in order to calibrate the turbine flowmeter. Luigi Serio and Bruno Vullierme assured that it would not be a problem to find a short period of time during the commissioning.

The test program was discussed with Rob van Weelderen. We planned to run at least one month with 12g/s of liquid helium. This flow will permit to cover the majority of our test. The test of the ultimate heat load with a consumption of 18g/s will rely on the cryogenic schedule of the SM18 hall. Therefore the campaign schedule test will be defined through the summer and will depend on the arrival of dipoles and quadrupoles to be tested.

3.2 TRANSDUCERS TO INSTALL

Some transducers (sensors) will record the shield temperature. Due to the lack of free connectors, we decided last year that their wires will be routed through the four modules up to the turnaround. Therefore, I soldered Platinum temperature transducers to their respective prepared wires and to install them on the punched shield. Indium foil and Stycast® was used in order to assure a good thermal contact with the Aluminum clips, used to hold transducers. Considering the installation status and my return date, I asked Sebastien Pelletier to ensure the final electrical connections.

As decided last September, Michel Gautier made available calibrated Penning and Pirani vacuum transducers. Both transducers will be used for the measurement of the insulation vacuum. He also lent us the control box, TPG300.

3.3 RECALIBRATION OF THE SAFETY PRESSURE VALVES AND RECALCULATION OF THE SAFETY PARAMETERS

Each safety pressure valves had to be recalibrate by TIS (Technical Inspection & Safety Commission) division in order to be used on the CERN experiment. Gabriel Ravier took care of this requested stamped. We decided that these valves would be temporally registered as CERN materials.

I had several meetings held with Raphael Vuillermet and Cedric Cheval, from TIS. The scope was to verify the safety parameter calculations. We reached a consensus for the use of certain coefficients, which was not clear through the engineering note. A excel worksheet used by Yuenian Huang in the engineering note, was provided to TIS. Thanks to this document we were able to reproducte consistant results. As a conclusion, a more conservative calculation would have been expected. Nevertheless, Raphael Vuillermet will issue the final document granting the authorization to install the US-IT-HXTU. No open issues remain regarding safety of the installation.

3.4 ELECTRICAL AND CABLING TOPICS

It is intended that the ST division at CERN will provide ACR with the assembly of the 41 cables. The list of materials is the responsibility of Sebastien Pelletier. We did update several parameters before we could contact the ST representatives.
On the request of Enrique Blanco and Juan Casas, last December, we sent American connectors to CERN in order to mate the one installed on the US-IT-HXTU. American devices are not compatible with any European tool, besides, it turned out that ST had to delay the cable assembly due to lost tools sent by FNAL. This delay is now compensated and cables are ready to be used by Enrique Blanco for the warm commissioning of his automates.

3.5 DAQ AND CONTROL SYSTEM

After many electronic communications, Enrique Blanco showed me concretely his progress on the regulation of the 1.8K cooling loop and automates that will be used for the test. His model is based on the predictive control for the LHC control and acquisition. He is currently finishing his PhD -"Application of non-linear control techniques to the 1.8 K Cooling loop for the LHC “. The PLC should be effective and reliable by the end of May.
We defined with Rob van Weelderen and Enrique Blanco, some parameters to implement the predictive control. The use of these constants will permit to control the cool-down. In April, they were testing the acquisition channels and electrical rack devices. The cold commissioning will permit to tune every parameters. Some more days may be requested in June in order to recalibrate some of the temperature sensors which would not meet the requested accuracy. This cold commissioning is foreseen for the end of May.

3.6 USER INTERFACE ELABORATION

Jean-Baptiste Bart will be in charge of the user’s interface via PC-view. Prior, a draft of the proposed interface was written and made available on the web page. As time did not permit to meet him, communications are mainly possible via e-mail, in order to cope with open issues. Enrique Blanco will oversee Jean-Baptiste Bart’s work.

4 OTHER POINTS OF INTEREST

4.1 PREPARATION OF THE PRESSURE AND LEAK TEST

We broached the subject of the pressure test with Raphael Vuillermet. It was decided that ACR would prepare the installation for the pressure test which will be performed with the consulting of a TIS representative. During the fabrication, pressure tests were performed by US-manufactures on each component (regarding the design pressure, FNAL specification and the AMS code). A test pressure of 5 bar was chosen to reflect the low operating pressure and the design pressure of components. A visual inspection will be requested at that moment. A procedure is available. Some more communication with TIS office will determine the final pressure test procedure.

There were some preliminary discussions with Bruno Vullierme and Gerard Bochaton concerning the adaptation of their pumping units. Prior we came to an agreement with Bruno Vullierme on the use of the CERN fitting pumping devices instead of shipping them from FNAL. The design and procurement of the interface for the fitting of the pumping devices was developed at FNAL.

We shipped to CERN devices that were used for leak checking at FNAL. Guidelines were explained to the CERN assembly team in order to perform the leak test and the pressure test once the US-IT-HXTU will be fully assembled. The step and procedure for these leak checks were also documented.

4.2 MEASUREMENT OF ACCELERATIONS WHILE SHIPPING

A sub-study was dedicated to follow-up the impact caused by the shipping to the hardware from FNAL to CERN. These observations will be important in order to estimate risks taken by shipping the LHC-IRQ magnets, in FY2002.
Our hardware was shipped by truck from FNAL to O'Hare, by plane to Paris, then by truck from Paris airport to CERN. At FNAL, we installed 24 basic impact indicators. One of the crates was equipped with the chart recorder. Ten days of data was registered. I checked the status of accelerometers. Raphael Vuillermet gave a previous status at the reception of the crates. Out of these statements, we worked in collaboration with Tom Nicol and we underlined that one of the modules did experience accelerations larger than 5-10 g, generally in the lateral direction (Y-axis). Unfortunately, a consistent conclusion regarding when large impacts happened can not be drawn. Actually, the chart recorder was installed in a crate, which experienced lower accelerations. Moreover, the registration scale of the device was not accurate enough; a 2-g full-scale device would have been more useful. Nevertheless, pertinent observations regarding the chart pointed out some acceleration of the order of 4-g along the Y-axis measured when the crate was handled at O'Hare airport. It is also possible to guess the time when crates were unloaded from the truck. Trucks were requested to be equipped with an air-ride suspension system.
Further investigations were initiated by Danzas shipping company in Geneva, that I contacted from CERN. An estimation of the shipping cost for the 19 FNAL magnets and 9 KEK magnets is currently under study. Eight flights could be foreseen for the 450 ton of hardware. The ultimate weight and fragility of the hardware dictate the high cost.

4.3 PREDICTIVE THEORETICAL MODEL

Before the trip, we worked with Yuenian Huang and Tom Peterson on a theoretical model which predicte the temperatures and the pressures that we intend to measure. We developped a table and an excel worksheet which are likely to summarize the expected parameters for key points on the test bench. We used the assumption of pertinent results from a small scale heat exchanger test to foresee temperatures and performance. This preliminary test was performed with the same copper corrugated tube used for the full-scale model, US-IT-HXTU. New parameters concerning the cryogenic supply will be taken into account in these models.

4.4 COMPANIES TO SUPPLY THE CORRUGATED COPPER TUBE

It could be that the current diameter of the corrugated HX tube is not large enough to remove the heat load due to the ultimate luminosity planned for the LHC. The results of the US-IT-HXTU will help determine this need, nevertheless we will work in parallel for such a supply. It turns out that CERN is working with companies that could help us with the choice of the corrugated HX tube ordering. As we had hard time to find American companies, which would meet these new requirements, I contacted a representative from Kabelmetal Company/Germany. The conclusion of this study is not available yet.

4.5 BULLETIN ARTICLE

Regarding the fact that is was the first hardware arriving from the USA for the LHC machine development, I was contacted to introduce this topic to the CERN's newspaper. Together with Rob van Weelderen and Tom Nicol, we estimated that it was too early to publish any large-scale article. Nevertheless, an article was issued for the CERN bulletin, describing the arrival of the hardware so far.

4.6 ACR& SM18 MEETINGS

I attended several meetings with the purpose to present the status of the US-IT-HXTU. Different information was part of agendas. Several meetings aimed at planning cryogenics uses in the SM18 hall. There were several meetings led by the ACR group, informing the staff about current projects developments. We heard about the ICEC conference in Bombay, the LHC workshop in Chamonix as well as the new cold compressor installation and run.

The KEK-US-CERN collaboration took place at CERN, from the 20 to the 21 of April. I joined to be informed on the status of KEK magnets. It was interesting for me to know a bit more on their work, which is complementary to the work done at Fermilab. Due to the busy schedule of this very last week, I was only informed through copies of other interesting presentations.

4.7 FUTURE

The 26th of April, two weeks of delay could be estimated for the assembly (ref. Installation Schedule). The best guess for the cold commissioning is June. From June onwards, the test will be conducted with the nominal luminosity simulation, with 12g/s of liquid helium consumption. The SM18 planning will determine later the use of 18g/s as well as the frequency of the cryogenic use.

At the current date, the cable system is ready, the final survey for the installation of the 1.4% slope is almost finished and the welding of the interconnection bellows will start soon. All the outstanding issues of the installation will hopefully be solved in the given time. Hence, extensive assembly work remains to be done on the interconnections, plus the pressure and leak tests.

If we take into account the competence of the CERN team and in so far as we provide them with procedures and frequent communications, we should not meet too many difficulties in the near future. Several problems have already emerged, but the assembly evolution is now driven by the need for results by July.

It is intended that Yuenian Huang and myself will go to CERN in June in order to assist the cool-down and the first measurement campaign.

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List of contact

February 28 – April 26, 2000
CERN, Geneva Switzerland

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Itinerary

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FNAL
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